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Investigating sea water influence and water quality assessment for different purposes in densu delta wetland, Accra, Ghana

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ABSTRACT

This study looks at the effect of the sea water is having on the Densu delta wetland. The objective of this work is to assess the hydro- chemical dynamics of the surface water from the Densu delta using hydro chemical parameters, stable isotopes- oxygen-18 and deuterium and also asses the quality of the surface water for purposes like irrigation using SAR, %Sodium and other modules. Samples of surface water were taken for physico-chemical analysis. The samples were analysed for physical and chemical parameters and the stable isotopes (^{18} O and D_2O). The results from the stable isotopes have shown that the quality of the surface water is being affected by slight mixing with sea water. From the SAR calculation, 62% and 38% of the water was within the excellent and good category respectively and none were within the doubtful and unsuitable category respectively. Calculation of % sodium showed that about 5 out of 8 samples have high sodium percent (above 60%) and are not suitable for irrigation purposes as per classification of Eaton 1950. From the Richards diagram, approximately 12.5% fall within good category; 75% in the category of doubtful; 12.5% within unsuitable category. Approximately 50% of the samples were found to be good by RSC index; 37% fall within the doubtful category and 13% unsuitable. A high percentage was within permissible ranges for TDS. The results suggest that generally water samples are suitable for domestic and irrigation purposes under normal temperature and pH condition.

Introduction

The Densu delta wetland is a ramsar site. The Ramsar site is a habitat for several species of long distance migratory birds using the East Atlantic Flyway (Ofori, 2005). The area supports about 57 species of seashore birds with an estimated population of 35000 and about 15 species of finfish belonging to 14 genera and 9 families with sarotherodon melanotheron and Tilapia zilli as the dominant fish species. Three species of marine turtles nest on the beaches, i.e. Lepidohelys olivacea, Chelonia mydas and Dermochelys coriacea. Scattered stands of mangrove (Avicennia africana) occur at the site. (Koranteng K. A. 1995b) .The Wetland also provides space for storing surface waters where intense biological processes occur. Water is one of the main wetland resources, the availability and quality of which always play important roles in determining not only where people can live, but also their quality of life (Solley *et al.*, 1995). The dumping of refuse, discharge of industrial and domestic sewage, as well as run-off from agricultural farms into surface water also increases the chemical and organic loading of the wetlands thereby decreasing the dissolved oxygen content necessary for aquatic organisms. The ecosystem too will be threatened since the habitat of several organisms like fishes and birds may be destroyed due to pollution In the coastal areas, the reduction of the input from upstream sources leads to increase intrusion of sea water into the water table, and hence, soil salinisation. The result is change in species composition as salt sensitive species are replaced by more salt-tolerant ones; farming in the area in the area may also be affected.

The objectives of the study were achieved through the determination of physico-chemical parameters in the wetland and also by the use of environmental stable isotopes of oxygen (^{18}O) and hydrogen (^{2}H) contents in order to identify evaporation effects as well as the different pollution sources.

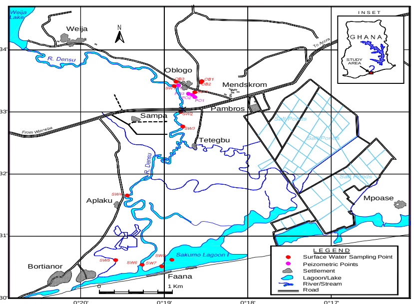

Fig.1 Map of Study area

Materials and Methods

Study area

The study area is located on latitudes $5^0 30'48^0$N and $5^0 33'32^0$N and longitudes $0^0 18'49^0$W and $0^0 19'35^0$W. The area is also a Ramsar site, which is located in the south-western part of central Accra, the nation’s capital. The Densu delta wetland is close to the confluence of the Densu River with the Atlantic Ocean in the Accra Metropolis of Ghana (Figure 1).

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It is located approximately 11km to the Southwest of Accra and is traversed by the Accra-Takoradi-Axim highway. Some communities of interest in this wetland are Oblogo, Aplaku, Tetegbu, and Bortianor. The wetland is fed mainly by the Densu River, which has been dammed a few kilometres up-stream (Weija dam) to supply water to some parts of Accra. The study area falls within the dry equatorial climate region of Ghana (Teley, 2001) with the climate governed by three district air masses, namely; the monsoon, the harmattan and the equatorial air masses.

Sampling and analytical procedure

Sampling was conducted from August to December, 2008. Samples were collected from all the sampling points (Fig. 1). At each sampling point, water and sediments were collected. Samples of water (SW1, SW2, SW3, to SW8) were taken from Oblogo were taken along the river to Bortianor. The sampling bottles were pre-conditioned with 5% nitric acid and later rinsed thoroughly with distilled de-ionised water. At each sampling site, the polyethylene sampling bottles were rinsed at least three times before sampling was done. The collection of the samples from the river was done with hand gloves. The direction of the flow of the river was faced and the particles in the river was disturbed by the feet and allowed to settle down before sampling. Pre-cleaned polyethylene sampling bottles were immersed about 10 cm below the water surface. Samples for the measurement of the isotopic composition of the waters were also collected separately into 50 mL bottles and filled to the brim without trapping any air bubbles.About one litre of the water samples were taken at each sampling site. The water samples were filtered using a pre-conditioned plastic Millipore filter unit equipped with a 0.45 µm filter membrane (Gelman Inst. Co, London). Two sets of water samples were collected at each sampling point. The samples were kept over ice in an ice chest and transported to the laboratory. The samples were kept in a refrigerator at about 4°C until analysis was performed. In situ measurements of pH, Total dissolved solids and Electrical conductivity were conducted. The analysis for major ions was done with the ion chromatograph.

All stable isotope values in this study are given as (δ) values in per mil (‰) against the international Vienna Standard Mean Ocean Water (V-SMOW, normalised to V-SMOW/SLAP scale) as defined by Eq. (1):

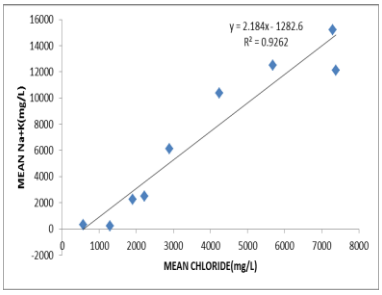
$$\delta = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000 \qquad (1)$$

Results and Discussion

Water Chemistry

Among major cations, Na^+ was generally dominant representing on average 95% of all the cations. Calcium and Potassium ions were of secondary importance, representing on average 2.2% and 1.86% of all cations, respectively. Magnesium ion was almost absent, representing on average 0.84% of all the cations. Among the major anions, the concentrations of chloride, bicarbonate and sulfate ions lie in between 212 and 8600, 34.8 and 329.4, 5.98 and 157.5 mg l^{-1} with a mean of 3906.58, 153.24 and 41.08 mg l^{-1}, respectively. The order of their abundance is $Cl^- > HCO_3^- > SO_4^{2-}$, contributing on average (mg l^{-1}), 94.9%, 3.95% and 1.06% of the total anions, respectively.

The sum of sodium and potassium ions distribution seems to follow the same trend as chloride. The graph of Na + K against Cl^- in surface water has a strong positive correlation.



The high levels of the chloride could be due influence of the sea on the wetland. The electric conductivity (EC) varies from 150 to 34120µS/cm indicating that there are probably fresh water (<500 µS/cm), marginal water (500-1500 µS/cm) and brackish water types (>1500 µS/cm) in the area. Total dissolved solids ranges from 182 to 14641 with an average of 2699.83 mg l^{-1}. The pH value of the delta is neutral to slightly basic pH of 6.4- 8.1 with a mean value of 7.51.

Environmental isotopes

Environmental isotopes oxygen-18 (^{18}O) and deuterium (^2H) have been used to determine any relationship between the river water as it moves towards the sea water and the sea water. Fig. 2 shows a plot of oxygen-18 and deuterium in surface water from the delta. The points plot below the local meteoric line for Ghana Akiti, (1980). This shows an evidence of the deviation of surface waters slightly from the rainfall in the vicinity of sea water due to evaporation or possible mixing of river water with sea water. The slight enrichment shown by the surface water (^{18}O ranges from-0.68 to -1.82 and ^2H ranges from -2.2 to -4.9) could be due to a possible slight mixing of sea water. This is because seawater is very much enriched in oxygen-18(0.02‰) and deuterium (0.10‰) compared to river water. In order to verify possible mixing with sea water, a theoretical sea water point was plotted on curves as shown in fig.3. It is clear from fig.3 that the mixing line in the surface water passes through to a plot of theoretical sea water point. This suggests a possible mixing is between sea water and river water. This could happen during high tides when the sea water moves into the river water.

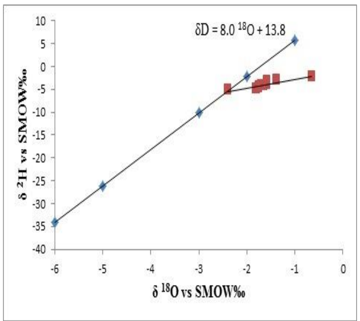


Fig.2: A regression line of δD-δ^{18}O of the Local Meteoric Water Line (LMWL) with surface water samples in the study area

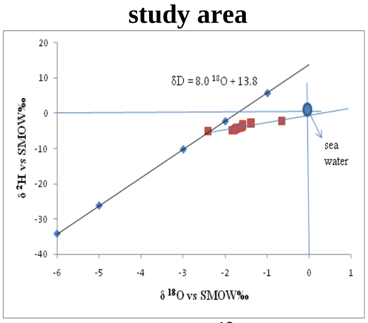


Fig.3 A regression line of δD-δ^{18}O of the Local Meteoric Water Line (LMWL) with surface water and theoretical sea water samples in the study area

A plot of chloride concentrations(Fig 4) of surface water and sea water against oxygen-18 gives a curve that showed a tendency towards the sea water therefore it is therefore possible that sea water is encroaches into the Densu river during high tides as indicated previously.

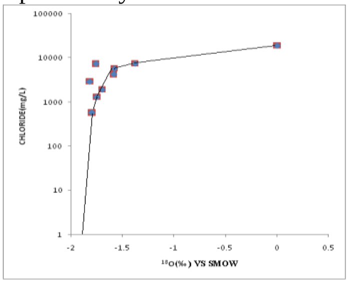


Fig.4 A plot of chloride against oxygen-18 in surface water samples and theoretical sea water points

It is therefore possible that as the sea water moves towards the river, the pressure of the water meets with that of the incoming river water at various points.

Suitability for Irrigation Use

The water quality evaluation in the area of study is carried out to determine their suitability for agricultural purposes. The suitability of water for irrigation is contingent on the effects on the mineral constituents of the water on both the plant and the soil. In fact, salts can be highly harmful. They can limit growth of plants physically, by restricting the taking up of water through modification of osmotic processes. Also salts may damage plant growth chemically by the effects of toxic substances upon metabolic processes. Salinity, sodicity and toxicity generally need to be considered for evaluation of the suitable quality of water for irrigation (Todd 1980; Shainberg and Oster 1976). Parameters such as EC, percent sodium and sodium adsorption ratio (SAR) and Standard diagrams (see figure 3 and 4) were used to assess the suitability of water for irrigation purposes.

Salinity Hazard

Based on the US Salinity Laboratory classification (1954) (see Figure 5) the salinity hazard for water samples in Densu delta is classified as medium (12.5%), high (75%) and very high (12.5%). Most of the water samples belong to high salinity hazard (C3) as per the salinity hazard classification in the delta. None of water samples had low salinity contamination. Water that falls in the medium salinity hazard class (C2) can be used in most cases without any special practices for salinity control. However, water samples fall in the high salinity hazard class (C3) may detrimental effects on sensitive crops and adverse effects on many plants. Such areas require careful management practices. Very high salinity water (C4) is not suitable for irrigation under ordinary conditions but may be used for salt tolerant plants on permeable soils with special management practices. Evaporation is the major cause of salinization in the delta. Moreover, irrigation with saline water, dissolution of the chemical fertilizers by irrigation water and industrial and municipal waste disposal increases the rate of salinization. (A. Rouabhia et al. 2009, Andradea et al. 2008).

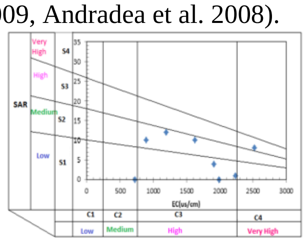


Fig 5 Salinity Diagram for Classification of Irrigation Waters (Based on Richards 1954)

Alkali Hazard

Although sodium contributes directly to the total salinity the main problem with a high sodium concentration is its effect on the physical properties of soil. While a high salt content (high EC) in water leads to formation of saline soil, high sodium content (SAR) leads to development of an alkaline soil. Irrigation with Na-enriched water results in ion exchange reactions: uptake of Na^+ and release of Ca^{2+} and Mg^{2+}. This causes soil aggregates to disperse, reducing its permeability (Tijani 1994). The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed as the sodium adsorption ratio (SAR).The SAR value for each water sample was calculated by using the following equation (Richard, 1954):

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \qquad (2)$$

Where the concentrations are reported in meq/l

From the SAR calculation, 62% and 38%of the water was within the excellent and good category respectively and none were within the doubtful and unsuitable category (figure 6).

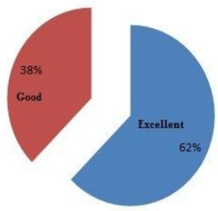


Fig 6 Water quality based sodium percent water class (Wilcox, 1955)

Percent sodium ($\%Na^+$) is also widely utilized for evaluating the suitability of water quality for irrigation. The $\%Na^+$ is computed with respect to relative proportions of cations present in water, where the concentrations of ions are expressed in meq/l, using the following formula:

$$Na\% = \frac{Na^+}{(Na^+ + K^+ + Ca^{2+} + Mg^{2+})} \times 100 \qquad (3)$$

Excess Na^+, combining with carbonate, leads to formation of alkaline soils, whereas with Cl^- saline soils are formed. It is observed that about 5 out of 8 samples have high sodium percent (above 60%) and are not suitable for irrigation purposes as per classification of Eaton 1950. High percentage of Na^+ with respect to (Ca^{2+} ,Mg^{2+}, Na^+) in irrigation water, causes deflocculating and impairing of soil permeability (Singh, 2008).

Bicarbonate Hazard

Bicarbonate hazard is usually expressed in terms of RSC (Residual Sodium Carbonate). RSC is calculated using the following equation:

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \qquad (4)$$

In waters having high concentration of bicarbonates, there is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium bicarbonate (Sadashivaiah et al., 2008). Residual carbonate levels less than 1.25 mg/l are considered safe. Waters with RSC of 1.25-2.50 mg/l are within the marginal range. The continuous use of waters having RSC more than 2.5 meq/l leads to salt build up which may hinder the air and water movement by clogging the soil pores, leading to degradation of the physical condition of soil. RSC (2.5-4) can be used effectively with the addition of gypsum. Sodic soils could be used with gypsum addition and green manuring (Latha et al., 2002). Approximately 50% of the samples were found to be good by RSC index; 37% fall within the doubtful category and 13% unsuitable (figure 7).

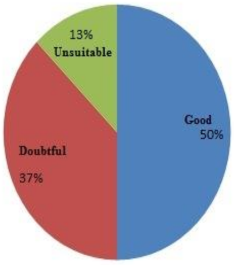


Fig 7 Water quality based on RSC (after Richards, 1954)

Conclusion

From the study, stable isotopes have successfully shown that the quality of the surface water is being affected by slight mixing with sea water. The slight enrichment shown by the surface water (^{18}O ranges from-0.68 to -1.82 and ^{2}H ranges from -2.2 to -4.9) could be due to a possible slight mixing of sea water. The SAR calculation also indicates that, 62% and 38% of the water was within the excellent and good category respectively and none were within the doubtful and unsuitable category respectively. Calculation of % sodium showed that about 5 out of 8 samples have high sodium percent (above 60%) and are not suitable for irrigation purposes as per classification of Eaton 1950. From the Richards diagram, approximately 12.5% fall within good category; 75% in the category of doubtful; 12.5% within unsuitable category. Approximately 50% of the samples were found to be good by RSC index; 37% fall within the doubtful category and 13% unsuitable. A high percentage was within permissible ranges for TDS.

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Appendix

Sodium percent water class (Eaton, 1950)

Na%	Water class
>60	Unsafe
<60	Safe

Water quality based on RSC (after Richards, 1954)

Class (mg/L)	Remark on quality
<1.25	Good
1.25-2.50	Doubtful
>2.50	Unsuitable

Salinity hazard classes

Salinity hazard class	EC (µS/cm)	Remark on quality
C1	100-250	Excellent
C2	250-750	Good
C3	750-2250	Doubtful
C4 and C5	>2250	Unsuitable

Sodium percent water class (Wilcox, 1955)

Na%	Water class
<20	Excellent
20-40	Good
40-60	Permissible
60-80	Doubtful
>80	Unsuitable